

## Restoration of Rare or Declining Natural Communities:

### *Beaver Dam Analogues and Post-Assisted Log Structures for Low-Tech Stream Restoration*

#### **Conservation Practice 643 - Specification Sheet**

Appendix A: Structure schematics and installation instructions. From Wheaton et al. 2019. [Low-Tech Process-Based Restoration of Riverscapes: Pocket Field Guide](#). Utah State University Restoration Consortium. Logan, UT.

## LOW-TECH STRUCTURE DEFINITIONS



### **P A L S**

#### **POST-ASSISTED LOG STRUCTURES**

- PALS are handbuilt structures that mimic and promote the processes of **wood accumulation**.
- Woody material of various sizes pinned together with untreated wooden posts driven into the substrate.

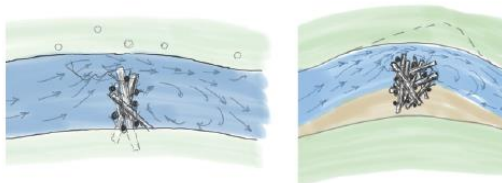


### **B D A s**

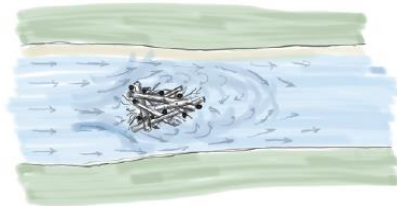
#### **BEAVER DAM ANALOGUES**

- BDAs are handbuilt structures that mimic and promote the processes of **beaver dam activity**.
- BDAs are a permeable, channel-spanning structure with a constant crest elevation, constructed with a mixture of woody debris and fill material to promote temporary ponding of water.

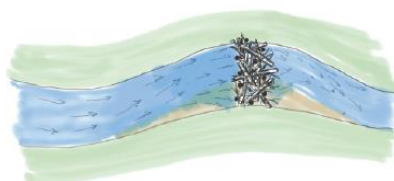
### **BANK-ATTACHED PALS**



### **MID-CHANNEL PALS**



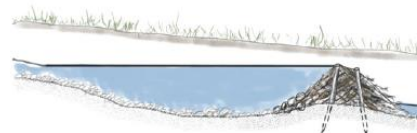
### **CHANNEL-SPANNING PALS**



### **POSTLESS BDA**



### **POST-ASSISTED BDA**



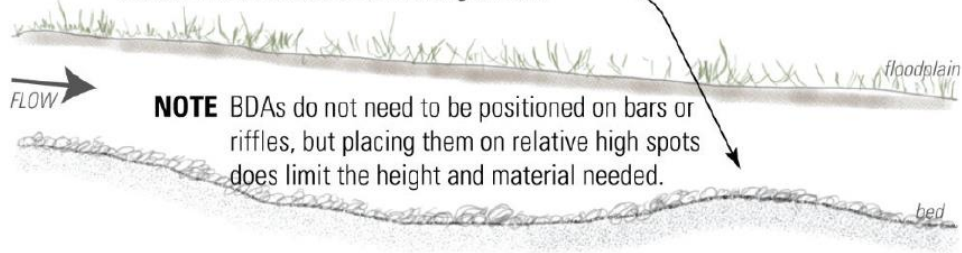
### **POST-LINE WICKER WEAVE**



# BEAVER DAM ANALOGUES

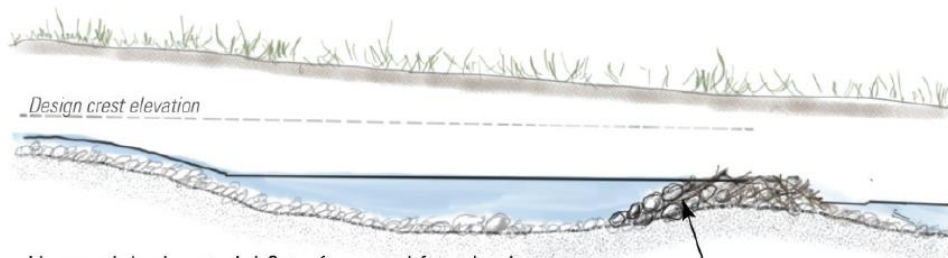
## STEP 1

Decide where to locate BDA along stream



## STEP 2

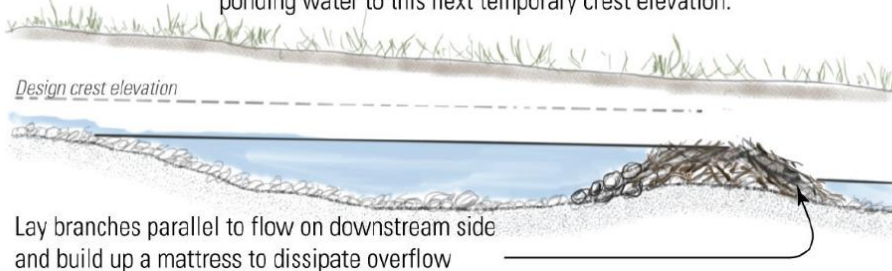
Build up first layer only to just above existing water surface and make sure crest is level across bed and its pooling water upstream to this temporary crest elevation



Use mud, bed material & turf sourced from backwater area combined with sticks of various sizes to build wide base. Make sure base is wide enough to accommodate designed height.

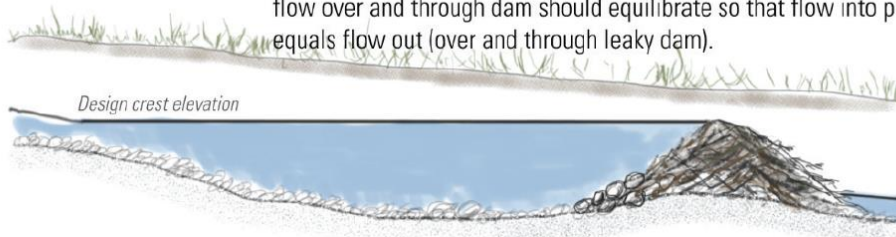
## STEP(S) 3

Build up subsequent layer(s) in 6 to 12" lifts, packing well with mud, turf, leaves, needles, sediment and other material until ponding water to this next temporary crest elevation.



## FINISHING STEP

Bring dam up to desired design crest elevation. Make sure crest of dam is perfectly level (so no preferential flow or weir exists). If stream is flowing, water should be backed up and ponding, but flow over and through dam should equilibrate so that flow into pond equals flow out (over and through leaky dam).



## HOW TO BUILD BDAs

- 1** Decide location of BDA dam crest orientation, configuration (e.g., straight or convex downstream), and crest elevation (use landscape flags if necessary). Position yourself with your eye-level at the proposed crest elevation of the dam (make sure it is < 5' in height). Look upstream to find where the pond will backwater to. Adjust crest elevation as necessary to achieve desired size of pond, inundation extent, and overflow patterns. If concerned about head drop (water surface elevation difference) over BDA, build a secondary BDA downstream with a crest elevation set to backwater into base of this BDA (and lessen head drop or elevation difference between water surface in pond and water surface downstream of BDA).
- 2** Build up first layer or course by widening base upstream and downstream of crest to flat height of 6 to 12" above existing water surface, and make sure it holds back water.
  - a.** If larger key pieces (i.e., larger logs, cobble or small boulders) are locally abundant, these can be used to lay out the crest position across the channel. Optionally, they can be 'keyed' in by excavating a small trench (no need to be deeper than ~1/3 of the height of key piece diameter) and place key pieces in and pack with excavated material.
  - b.** Lay out first layer of larger fill material, being careful not to go to higher than 6" to 12" above existing water surface. The first layer should be just high enough to backwater a flat water surface behind it.
  - c.** Using mud, bed material & turf (typically sourced from backwater area of pond) as fine fill material to plug up leaks, combine with sticks and branches of various sizes to build a wide base. Make sure base is wide enough to accommodate anticipated dam height (most dams will have a 1.5:1 to 3:1 (horizontal : vertical) proportions).
  - d.** Build up first layer only to top of key pieces from first layer. Make sure the crest is level across the channel and water is pooling to this temporary crest elevation.
- 3** Build up subsequent layer(s) in 6" to 12" lifts, packing well with fine fill material until ponding water to its next temporary crest elevation.
  - >** Repeat step 3 as many times as necessary to build up to design crest elevation.
  - >** Work a overflow mattress (laying branches parallel to flow) into dam on downstream side and build to provide energy dissipation to overtopping flows.
  - >** If desired, and time permits, attempt to plug up BDA with mud and organic material (small sticks and turf) to flood pond to crest elevation. Optionally, you can leave this for maintenance by beaver or for infilling with leaves, woody debris and sediment.

*continued >>*



## NOTES

- » The temptation is always to build up (in height) quickly without making sure each layer is holding back water well and is stable. A better dam results in building up to the design crest elevation slowly.
- » Overall dam height is best not to exceed the height of the people constructing it.
- » It is easier to build in systems that already have a perennial water source and flowing water, as you can see instantly how well your structure backs up water. It is possible to build in intermittent channels or areas you expect to receive water in the future, but you will not immediately mimic a beaver pond in such situations.
- » Much of the 'strength' of the dam comes from the messy carbon fiber matrix you are building with a mix of size and type of materials combined. Similar to concrete, the cement by itself is not strong, but the aggregate and/or reinforcing rebar is what gives the structure its strength.
- » Resist the temptation to overbuild the BDA.
- » A BDA that 'breaches' or 'blows out', just like natural beaver dams do, is not a 'failure' if designed to accommodate such a response. Often, BDAs that blow out or breach provide improved and more complex habitat.
- » If upstream fish passage is a concern, consider building features that make for flow variability that facilitate typical pathways through, over and around natural beaver dams. These can include ensuring overflow side channels that act as fish ladders, sloppier mattresses with micro pools, more branches in the mattress laid parallel to the flow, decreasing head drop for crest elevation of large dams, by building secondary dam(s) downstream that backwater up to base, leaving some porous pathways through dam for fish (and water) to get through.
- » Design life: < 1 year (note actual life may last many years or even decades).

## OPTIONS, CONSIDERATIONS & VARIATIONS

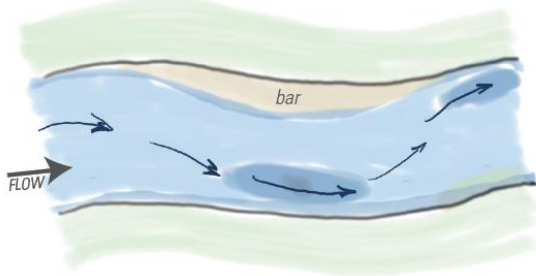
- » For **Step 2a**, it is not necessary to build with larger key pieces. Often building with a mix of smaller woody material and fine fill material is stronger. If woody key pieces are used, consider limbing (cut off branches) on side in contact with bed.
- » For **Step 2b**, if key pieces are limbed on the side that is in contact with bed, the branches removed from the other side can be used to help weave and wedge material in subsequent layers in. If this is done, make sure that limbs are trimmed at completion to design crest elevation.
- » Just like natural beaver dams, there are a huge number of variations in the woody fill material and fine fill material. In some riverscapes that lack woody riparian vegetation, or nearby woody material, beaver build very strong beaver dams out of nothing more than fine fill material.
- » If building a 'primary' dam (larger dam that tends to be deep enough to support an underwater entrance to a beaver lodge, consider backwater inundation extents relative to good bank-lodging opportunities (e.g., overhanging banks, vegetation and cover from predation).
- » If building multiple dams (typically secondary) in series, the dams within a complex tend to be positioned (spacing downstream) and built to heights that support flatwater from the crest of the downstream dam all the way upstream to the base of the next dam upstream (*see page 22*).



## DAM CREST ORIENTATIONS

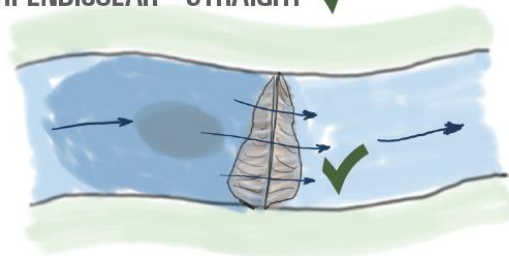
### UNDAMMED REACH

At low flows, and in the absence of dams, flow paths within the bankfull channel follow the thalweg and are shunted by bars.



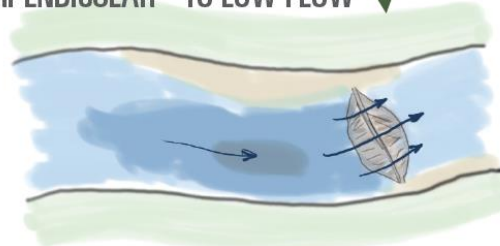
Since dams are built to a constant crest elevation, they essentially are a contour. Water flows perpendicular to the contour and over the dam crest, when the dam is maintained and/or intact.

### PERPENDICULAR - STRAIGHT ✓



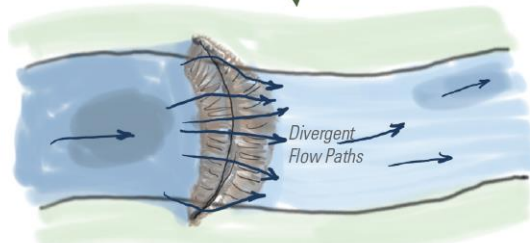
When dam crests span the bankfull channel, but are lower elevation than the adjacent floodplain, low flows are contained within the channel. Perpendicular orientations will back water up, and alter the flow paths to that of bankfull flows.

### PERPENDICULAR - TO LOW FLOW ✓



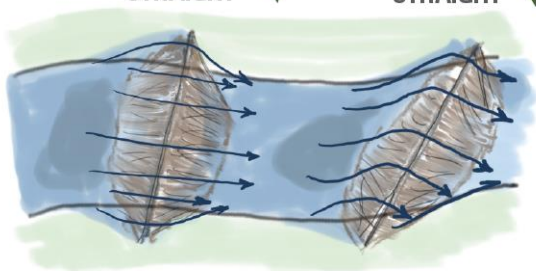
Smaller dams that just backup the low-flow channels often have an orientation perpendicular to the low flow, but at an angle to the bankfull flow patterns.

### CONVEX DOWNSTREAM ✓



Beaver dams are sometimes curved in a convex downstream orientation across the channel, which creates divergent flow paths over the dam. This flow pattern is effective at dissipating energy.

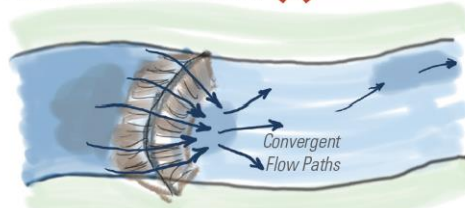
### PERPENDICULAR-STRAIGHT ✓



### ANGLED-STRAIGHT ✓

When dam crests are higher than bankfull and extend out onto floodplains, they can direct overflow onto those floodplains. However, a perpendicular, straight dam will direct most flow straight downstream. By contrast an angled dam will direct flow to one side of the channel (however the head drop tends to dissipate most of the flow energy).

### CONCAVE DOWNSTREAM ✗



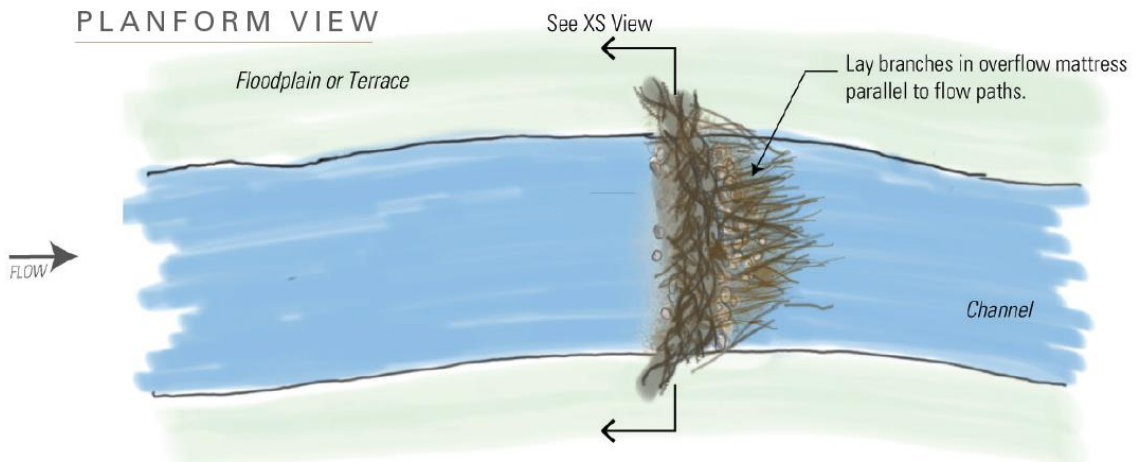
Beavers rarely build dams like Hoover Dam (and Hoover was not designed to withstand spill over the top). Concave downstream crests concentrate flow at the base of the dam, scouring out a deep pool, but also potentially undermining the dam integrity.

## POSTLESS BDA

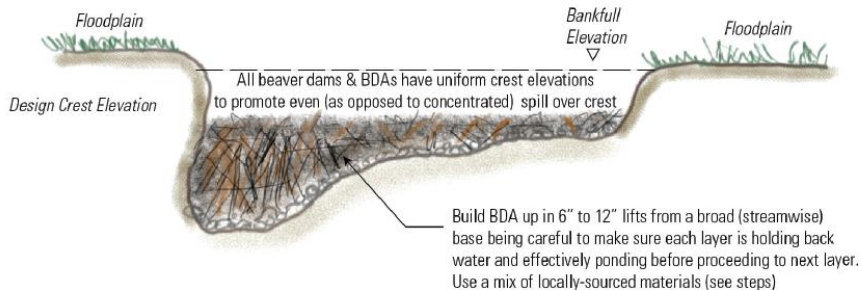
- BDAs are built to initially mimic a natural beaver dam (i.e., backwater upstream, such that a pond is created), but most BDAs are intended to promote beaver dam activity at some point thereafter.
- Many of the benefits of natural beaver dams, come from their ephemeral nature, and whether dams are actively maintained, blown-out, breached, filled in and/or abandoned.
- Postless BDA design are inspired by how beavers build dams; without fence posts, a hydraulic post pounder or heavy equipment. Like natural beaver dams, the postless BDA is appropriate in areas that can already support beaver dams.



### PLANFORM VIEW



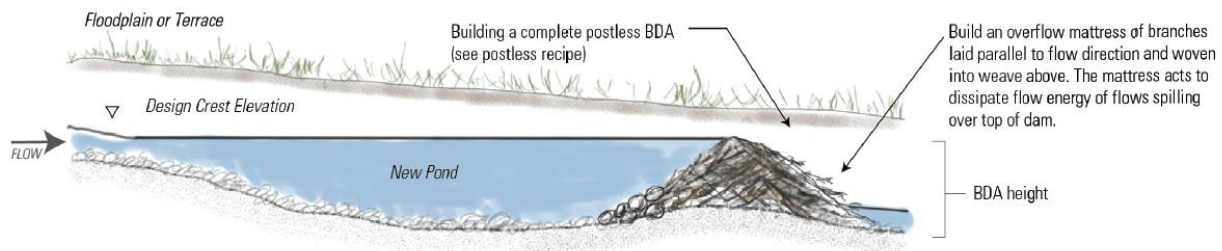
### CROSS SECTION VIEW



#### NOTE

The crest elevation is a critical consideration. In general, primary dams are taller than secondary dams, and usually wider (either extending onto bars, inset benches or floodplains, as to lower unit stream power). Secondary dams tend to just be tall enough to back-water up to the base of the next upstream dam. Secondary dams can be built higher to lower the head (elevation) drop of an upstream dam.

### PROFILE VIEW

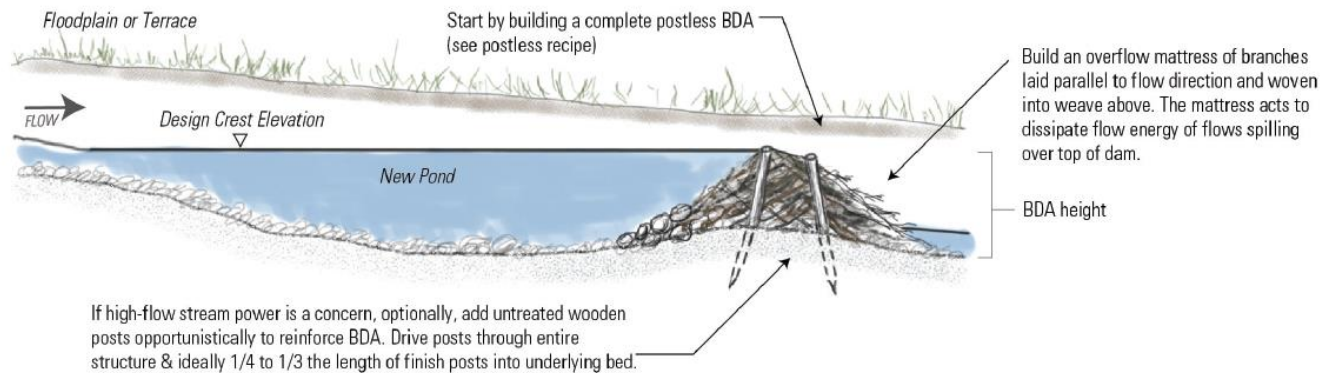


## POST-ASSISTED BDA

- Posts can provide some temporary anchoring and stability to help with initial dam stability during high flows in systems with flashier flow regimes or that produce larger magnitude floods.
- For situations where additional support during high flows is deemed necessary, our suggested practice is to start out following the instructions to build a postless BDA, and then simply add posts as extra reinforcement after the fact.

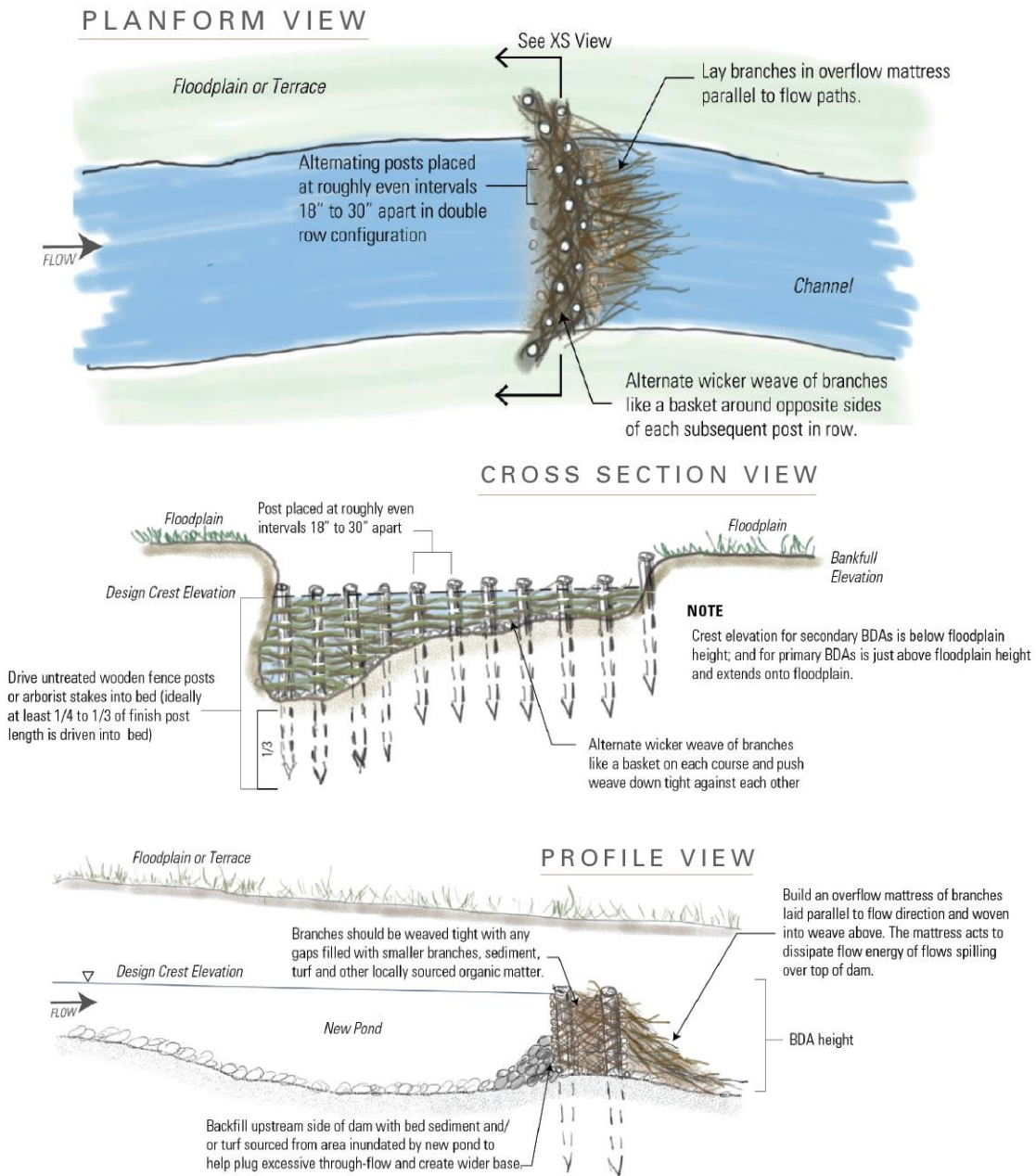


### PROFILE VIEW WITH POSTS



## POST-LINE WICKER WEAVE

- BDAs can be constructed using post-line wicker weaves, to initially mimic beaver dam activity and later promote it.
- Posts used to layout a crestline, and long branches are woven between the posts to provide most of the structure.
- Post-line wicker weaves have been used for at least 150 years as instream structures, but have most often been used in check-dam or weir designs, which have higher crest elevations along the banks, and concentrate flow over the middle of the structure. By contrast, post-line wicker weave BDAs have a constant crest elevation as to not concentrate flow at any point.



# POST-ASSISTED LOG STRUCTURES

## HOW TO BUILD PALS

- 1 Decide location of PALS, configuration (e.g., orientation and type of PALS) as part of the design of a complex of structures (multiple structures working together).
- 2 Position larger logs on the base of the structure to make the general shape of structure.
- 3 Limb branches from one side of the logs so that much of the log comes in contact with the bed to increase interaction between the flow and the structure, even at low flows.
- 4 Pin large pieces in place with posts; drive posts at angles and downstream to help hold wood in place at high flows.
- 5 Add more logs, and pack and wedge smaller material to fill spaces in the structure.
- 6 Build up the structure to desired crest elevation, but crest elevation need not be uniform.



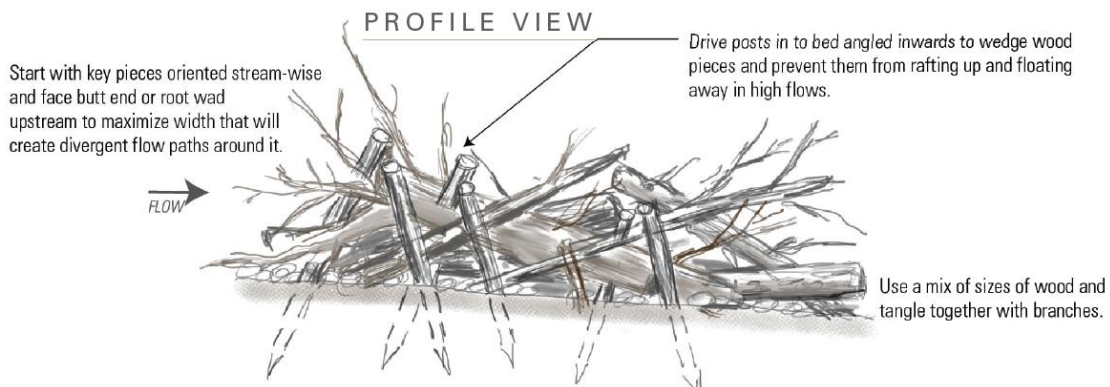
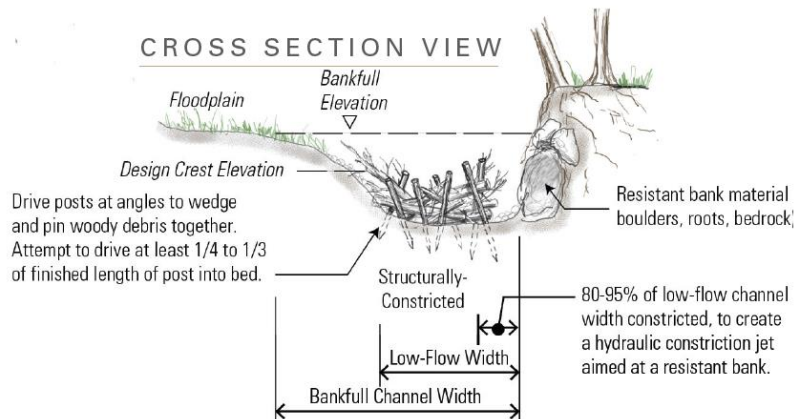
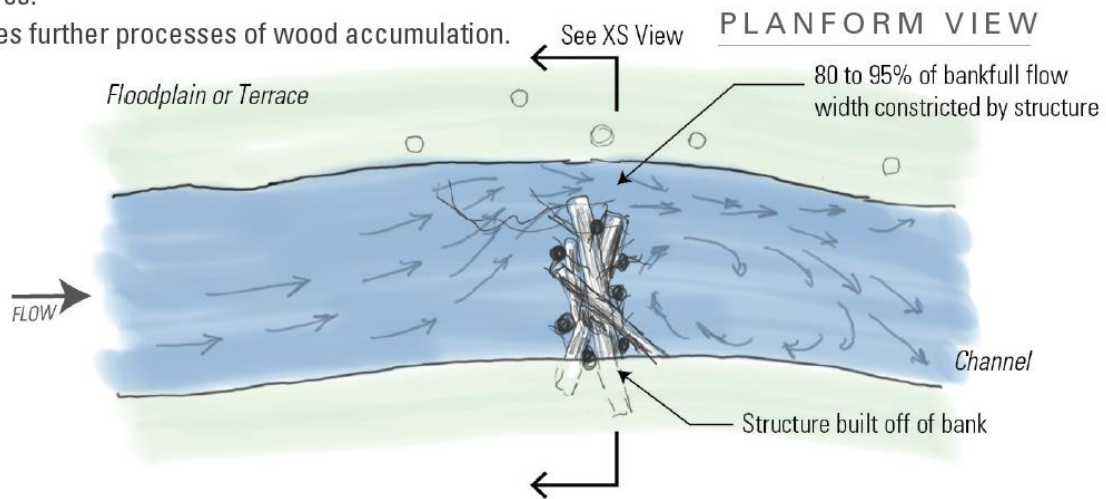
## OPTIONS & CONSIDERATIONS

- » Consider how much hydraulic purchase (interaction with flow) you want the structure to have and what flows (e.g., baseflows, typical floods, rare floods) it should engage with.
- » Build PALS with irregular shapes and branches and small debris sticking out in multiple directions (i.e., make a mess).
- » For PALS where flow over the top is anticipated, consider constructing a mattress of woody material on downstream side to dissipate pour over flow energy over-top of structure. Alternatively, if the intention is to encourage formation of a plunge pool, maybe build mattress incompletely, or not at all.
- » When building bank-attached and channel-spanning PALS, extend the structures onto the floodplain by wedging structure material into existing vegetation, trunks, roots or boulders on the floodplain. Build bank-attached PALS with a broader base (streamwise) where the structure attaches to the bank, to better shunt flows to the opposite bank
- » Locate bank-attached PALS across from hard features like boulders or roots to force a scour pool.
- » Build a broad base (streamwise) for channel-spanning structures relative to channel width so that the structure is not narrow and “wall like”. Use multiple lines of offset posts to build it wide.
- » Build mid-channel PALS with large and wide logs perpendicular to the flow on the upstream end of the structure to act like a natural root wad.
- » In general, the larger the structure relative to the channel width (i.e., constriction width), the larger effect it will have on hydraulics, and subsequently geomorphic change during high flows.
- » Not all woody structures need to have posts (i.e., ALS – assisted log structures). Large cobble and boulders, or wedging key pieces between existing trees, roots, can all serve the ‘temporary pinning’ function of posts if available.

## BANK-ATTACHED PALS

### VARIATION 1: TO FORCE A CONSTRICTION JET

- Creates convergent jet of flow between bank- or margin-attached structure and a resistant feature (e.g., bedrock bank, roots, wood) on opposite bank.
- Forces more variable hydraulics, which typically create a backwater eddy upstream of the structure, a large eddy in the wake of the structure, and divergent flow paths where the jet weakens.
- Promotes structurally-forced pool, riffle growth at the divergent jet, and eddy bar formation in the eddies. Upstream deposition stabilizes and grows the structures.
- Promotes further processes of wood accumulation.



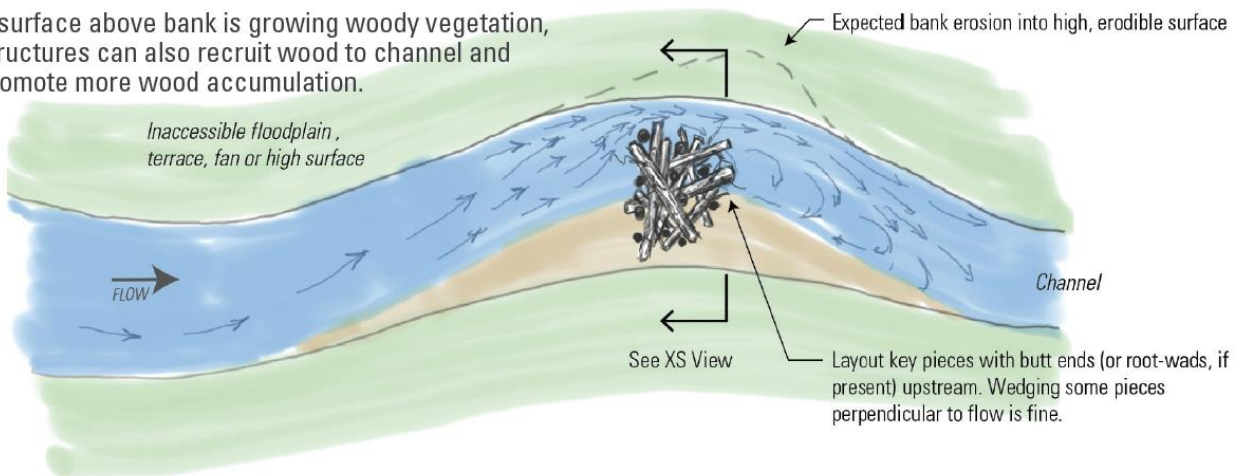
## BANK-ATTACHED PALS:

### VARIATION 2: BANK BLASTER

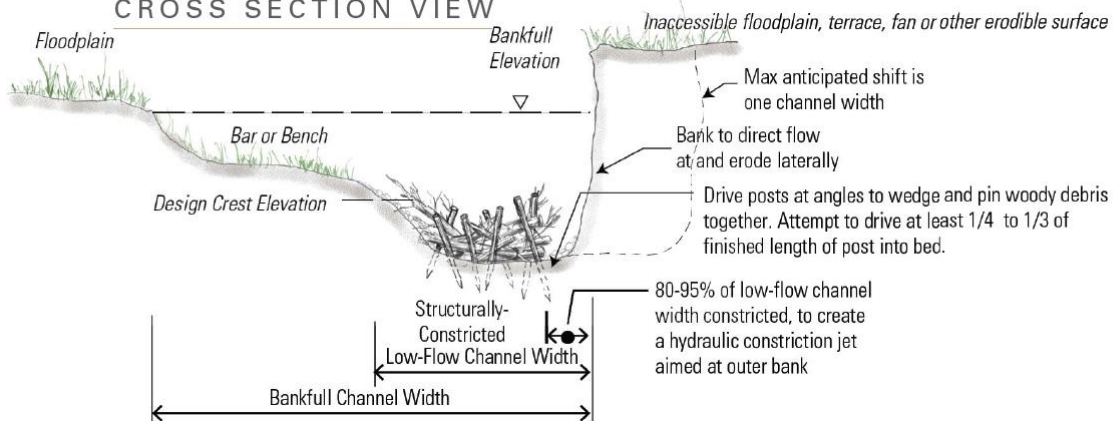
- Accelerates lateral widening via bank erosion of an erodible bank opposite of the structure.
- Shunting of flow forces more variable hydraulics, which typically create a backwater eddy upstream of the structure, an eddy downstream of structure, and temporary jet aimed at opposite erodible bank.
- Leads to lateral shift of channel (no more than one channel width typically). Further lateral migration occurs if bar growth continues on inside bend, further natural woody debris accumulates on structure, or subsequent treatment is extended off structure.
- If surface above bank is growing woody vegetation, structures can also recruit wood to channel and promote more wood accumulation.



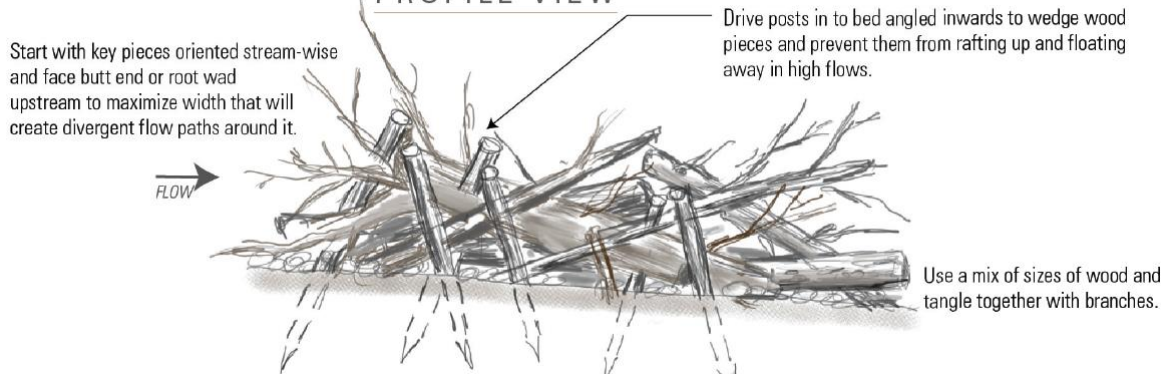
PLANFORM VIEW



CROSS SECTION VIEW



PROFILE VIEW

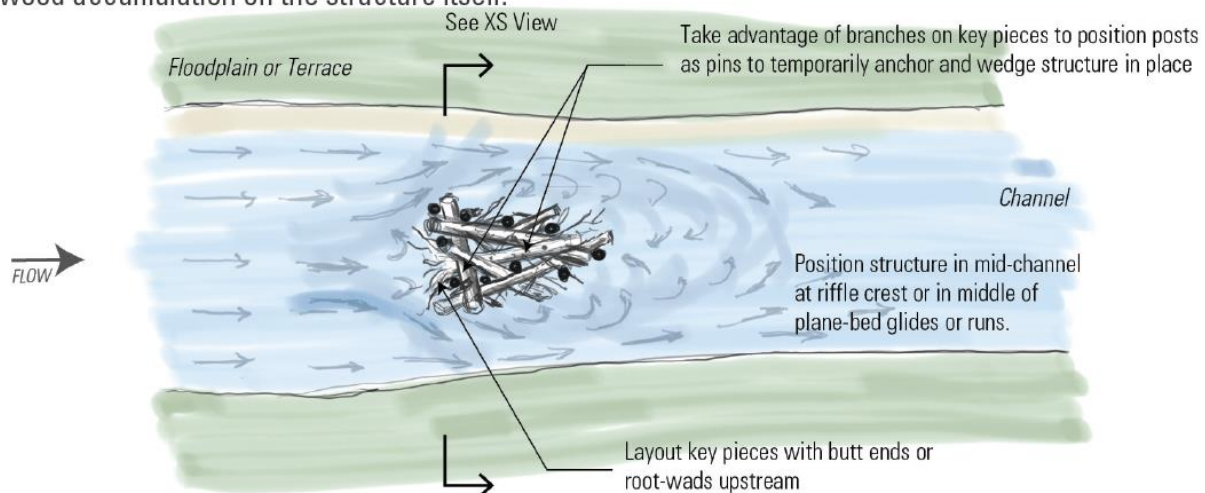


## MID-CHANNEL PALS

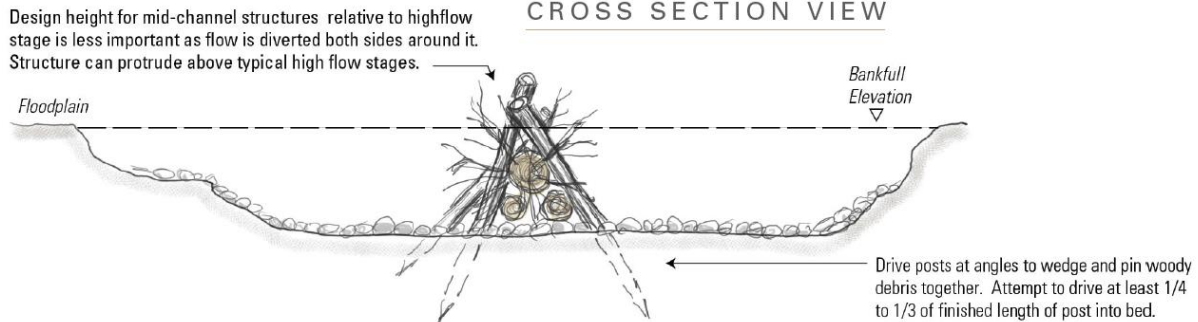
- Installed mid-channel to split flow around the structure.
- Forces more variable hydraulics, which creates an eddy downstream of structure.
- Can promote mid-channel bar development in place of planebed morphologies, encourage or promote diffluences, convert riffles into mid-channel bars and/or to dissipate flow energy.
- In larger channels, multiple mid-channel PALS can be used in close proximity and are often more effective than a single large structure.
- In all cases, the mid-channel PALS can promote the process of wood accumulation on the structure itself.



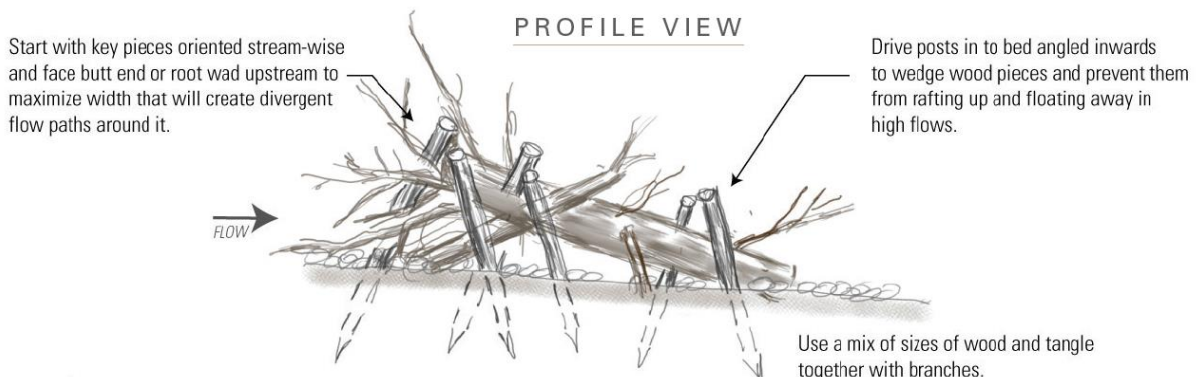
PLANFORM VIEW



CROSS SECTION VIEW



PROFILE VIEW

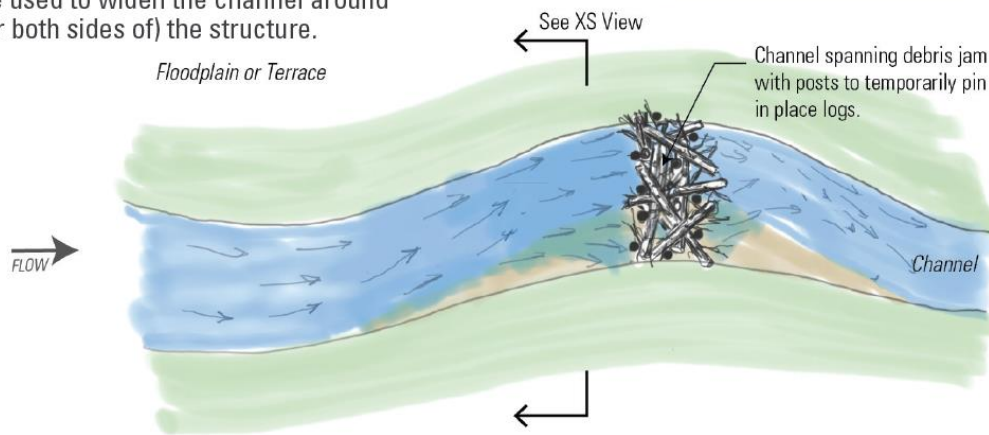


## CHANNEL-SPANNING PALS

- Bank-attached on both sides, such that even at low-flow there is some hydraulic purchase across most of the channel, acting to back-water flow behind it. Unlike a beaver dam (with a uniform crest elevation), channel-spanning PALS can have a variable crest elevation and rougher finish, and are generally built with much greater porosity.
- Over time, increased water depth and decreased velocity upstream of PALS encourages more wood accumulation, organic accumulation and sediment deposition, all of which can act to stabilize the structure.
- If crest elevations are higher than adjacent floodplain(s), it can increase frequency of floodplain inundation, force new diffluences, and/or promote avulsions.
- Can be used to widen the channel around (one or both sides of) the structure.

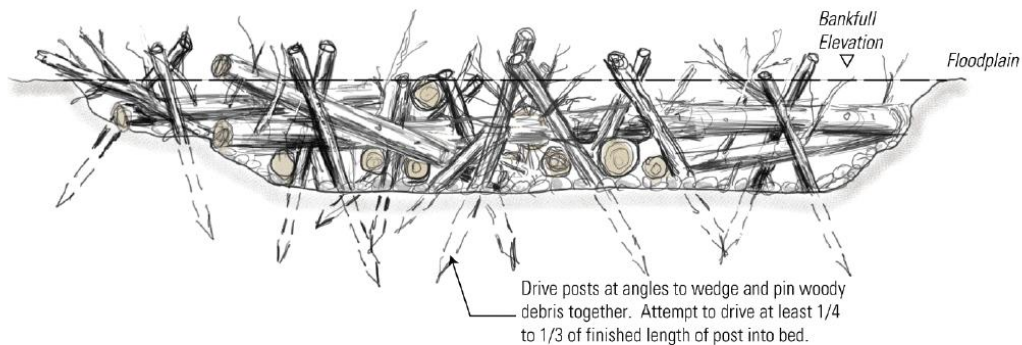


PLANFORM VIEW



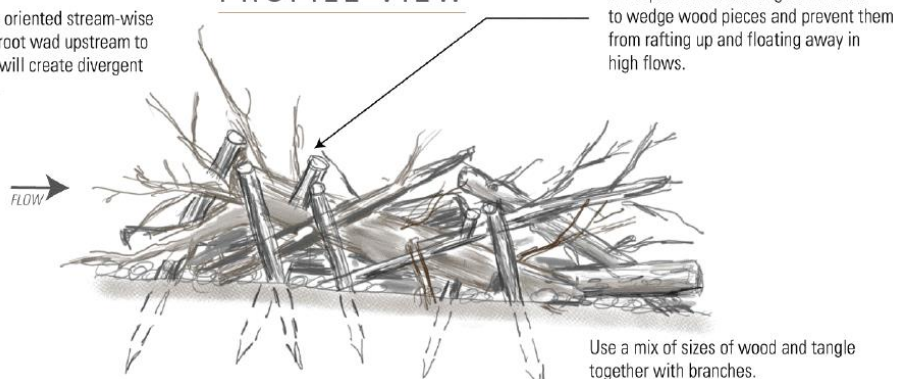
Design height for channel-spanning structures is important. If it is intended Structure can protrude above typical high flow stages.

CROSS SECTION VIEW



PROFILE VIEW





Start with key pieces oriented stream-wise and face butt end or root wad upstream to maximize width that will create divergent flow paths around it.



# TOOLS TYPICALLY USED

- » PPE (personal protective equipment): closed-toe work boots, full pants, gloves, hardhat, eye protection and ear protection; optionally: dry suit or waders
- » Cutting tools: loppers; optionally: chainsaw, hand saw(s), and pruning shears – for sourcing, trimming and cutting to size woody fill material
- » Digging tools: shovel(s); optionally: pick-axe and/or digging bars – for sourcing finer fill material
- » Five-gallon buckets: for filling and moving finer fill material from source areas to BDA
- » Cam straps (optional): helpful to bundle together branches for easier hauling

# POST DRIVER OPTIONS

	Sledge Hammer	Post Driver Manual Powered	Hand Operated Gas Powered	Hand Operated Hydraulic Powered
				
Equipment Cost	\$	\$	\$\$	\$\$\$
Operator Expertise	Unskilled	Unskilled	Moderate	Moderate
Ease of Deployment	Easy	Easy	Easy	Moderate
Max Diameter of Post	0.5 - 2"	0.5 to 2.5"	1" to 2.5"	1" to 4"
Effectiveness / Scalability	Low	Low	Moderate	High

# POST OPTIONS

Posts are used to provide temporary stability or pins when building many low-tech restoration structures. There are many commercially-available post options (e.g., fence posts), but a premium price is charged for consistency, larger diameter, and straight poles (e.g., peeler cores and lodge pole). Smaller diameter (e.g., 2" to 3") posts and/or tree stakes (1.5" to 2" diameter) are cheaper, and often available from fuels reduction or non-commercially viable slash from timber harvest operations. Since posts are driven into substrate, they need to be pointed at tips. Pointing can be done by supplier or by an experienced chainsaw operator with four cuts.

